Supplemental Biological Evaluation of Fall Webworm on the Allegheny National Forest

Prepared by:

Lindsay M. Wolf
Biological Science Technician

And

Richard M. Turcotte
Entomologist

USDA Forest Service

Northeastern Area State and Private Forestry

Forest Health Protection

180 Canfield Street

Morgantown, WV 26505

Prepared for

Allegheny National Forest

USDA Forest Service

February 2013

(3413 NA-13-03)

TABLE OF CONTENTS

Abstract 3
Purpose and Need 3
Project Location/Description 3
Project Objectives 4
Project Methods 4
MODIS Satellite Data 4
MODIS Accuracy assessment (Error matrix and Kappa Statistic) 7
Results 7
MODIS satellite data 7
Discussion and Recommendations 9
Acknowledgements 11
References 12

Biological Evaluation of Fall Webworm on the Allegheny National Forest

Abstract

During the late summer of 2011 and 2012, the Allegheny National Forest (ANF) experienced an outbreak of a native defoliator, the fall webworm (*Hyphantria cunea* Drury (Lepidoptera: Arctiidae)), mainly on black cherry (*Prunus serotina*) trees. Moderate resolution imaging spectroradiometer (MODIS) normalized difference vegetation index (NDVI) data from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET) detected 11,440 acres of detectable change in 2011 and 20,572 acres of detectable change in 2012. Field surveys of individual pixels were used to create an error matrix to assess the accuracy and agreement between the MODIS NDVI satellite data and field observations. Field surveys of 33 pixels in 2011 and 64 pixels in 2012 detected fall webworm activity at ~79 percent of the sites with defoliation occurring. Agreement between MODIS NDVI data and field surveys was 42.4 percent in 2011, and 20.3 percent in 2012 when comparing the binary response of detectable and undetectable change with the field assessments of defoliated and undefoliated pixels. The overall accuracy (agreement) for field data and MODIS NDVI change data when categorizing by level of change dropped to 30.3 percent in 2011 and 36.4 percent for 2012. Kappa statistics calculated for both years showed very poor to no agreement between field and MODIS NDVI data (Kappa statistic = 0.0 to 0.1). Because the fall webworm is a late season defoliator and its outbreaks typically last 1 to 2 years, it is normally not considered a forest pest or an agent of high tree mortality, although those trees that experience high defoliation will likely have reduced growth and branch dieback. Fall webworm control measures are not recommended in general forest areas of the Allegheny National Forest. However, we recommend that the Forest incorporate annual insect and disease monitoring into management plans for high-value areas such as campgrounds and, if needed, apply both long- and short-term insect and disease treatment strategies to minimize impacts and meet resource objectives.

Purpose and Need

The Morgantown Field Office (Mumford and Norton) received a request from the Marienville Ranger District, located in the Allegheny National Forest, to evaluate the impact of fall webworm (FWW) activity. The request came from District Ranger Rob Fallon, who recently observed fall webworm activity across the ANF. The MFO undertook this project and prepared an original biological evaluation of FWW activity for the ANF in 2011. This is a supplemental evaluation to address a second year of defoliation within the ANF.

Project Location/Description

The Allegheny National Forest is located in northwestern Pennsylvania in parts of Elk, Forest, Jefferson, McKean, and Warren counties (41º45’N, -79º00’W). The ANF covers approximately 517,000 acres of which 463,000 acres are forested. The ANF lies within the hemlock-white pine-northern hardwood region (Braun, 1950). The hemlock-northern hardwood forest type of pre-settlement times was composed mainly of eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*), and it has been replaced by the current mixed upland hardwoods and

cherry-maple (Allegheny hardwood) types (Morin et al., 2006; Whitney, 1990). Currently, black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) are the most abundant species in the ANF (Morin et al., 2006).

Project Objectives

The objectives for this supplemental evaluation were to 1) assess the location and extent of fall webworm defoliation in 2012, 2) identify areas with two years of defoliation, 3) assess the agreement between field observations and MODIS NDVI change on single pixels, and 4) determine the need for management activities on the Allegheny National Forest.

Project Methods

MODIS Satellite Data

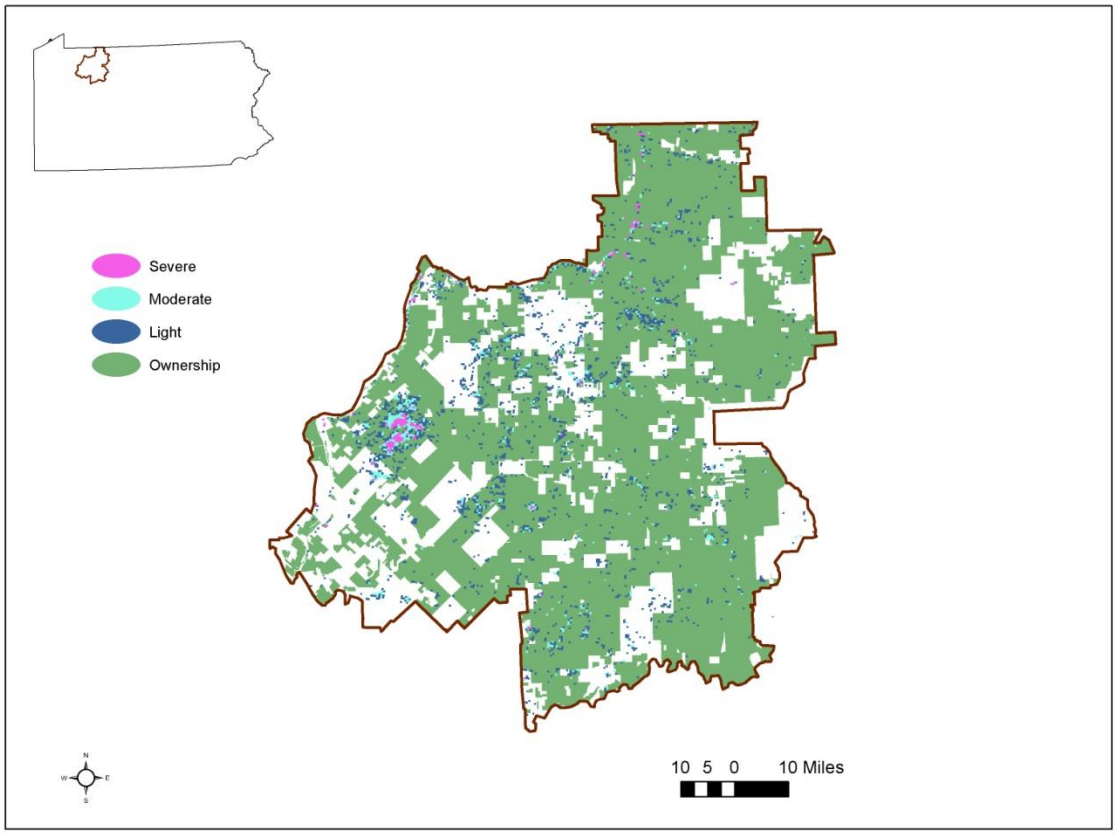

Figure 1. Forest disturbance on the Allegheny National Forest, Forest Disturbance Mapper change assessment for September 29, 2011.

We used moderate resolution imaging spectroradiometer (MODIS) data to assess fall webworm activity in the ANF. We acquired MODIS and normalized difference vegetation index (NDVI) data with a resolution of 240 m² (~14 acre pixel) and 16-day interval composite data beginning

on September 29, 2011 and September 22, 2012, from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET), work group (figure 1, 2 and 3). The data collected from this early warning systems uses the NDVI to measure and contrast the visible and near infrared spectral bands (Spruce et al., 2011). The NDVI relies on sensors aboard satellites to measure the absorption of red radiation by leaf pigments and chlorophyll and the scattering of the near infrared band by foliage to detect change (Beck et al., 2006). We compared the NDVI values of each pixel to a 5-year historical baseline value and determined the percent change.

We then separated the NDVI values into four classes based on the percent change from baseline: none (0 percent), light (1-9.9 percent), moderate (10-19.9 percent), and severe (>20 percent). We imported the MODIS data into the ARCMAP 10 (ESRI, Redlands, California) geographic information system (figure 1and 2). We then manually grouped clusters of pixels showing detectable change into discrete areas of interest across the ANF.

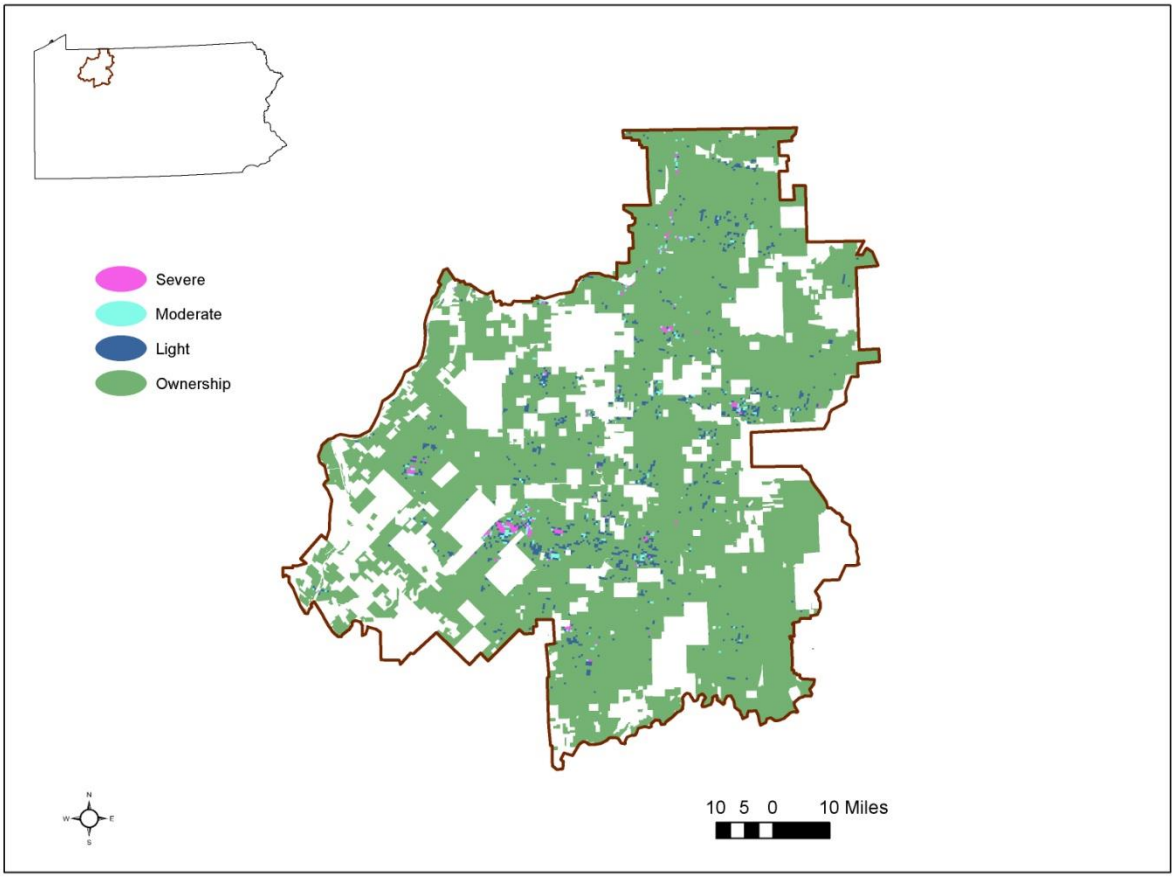

Figure 2. Forest disturbance on the Allegheny National Forest, Forest Disturbance Mapper change assessment for September 22, 2012.

We transformed the class data into binary data (detectable change/undetectable change) and used ARCMAP to create 1 mile buffers around the roads in each cluster. We used ARCMAP to

randomly select 20 pixels from each of the binary data classes within the buffered areas and then created field maps that included the UTM coordinates of each pixel.

Field crews were not told if change was detected in the pixel or not. Field crews then used the GPS coordinates and field maps to survey the entire ~14-acre pixel. These field assessments occurred on October 10 and 11, in 2011, and September 26 and October 3 and 4, in 2012. At each pixel crews were asked to 1) note the presence/absence of fall webworm (based on the

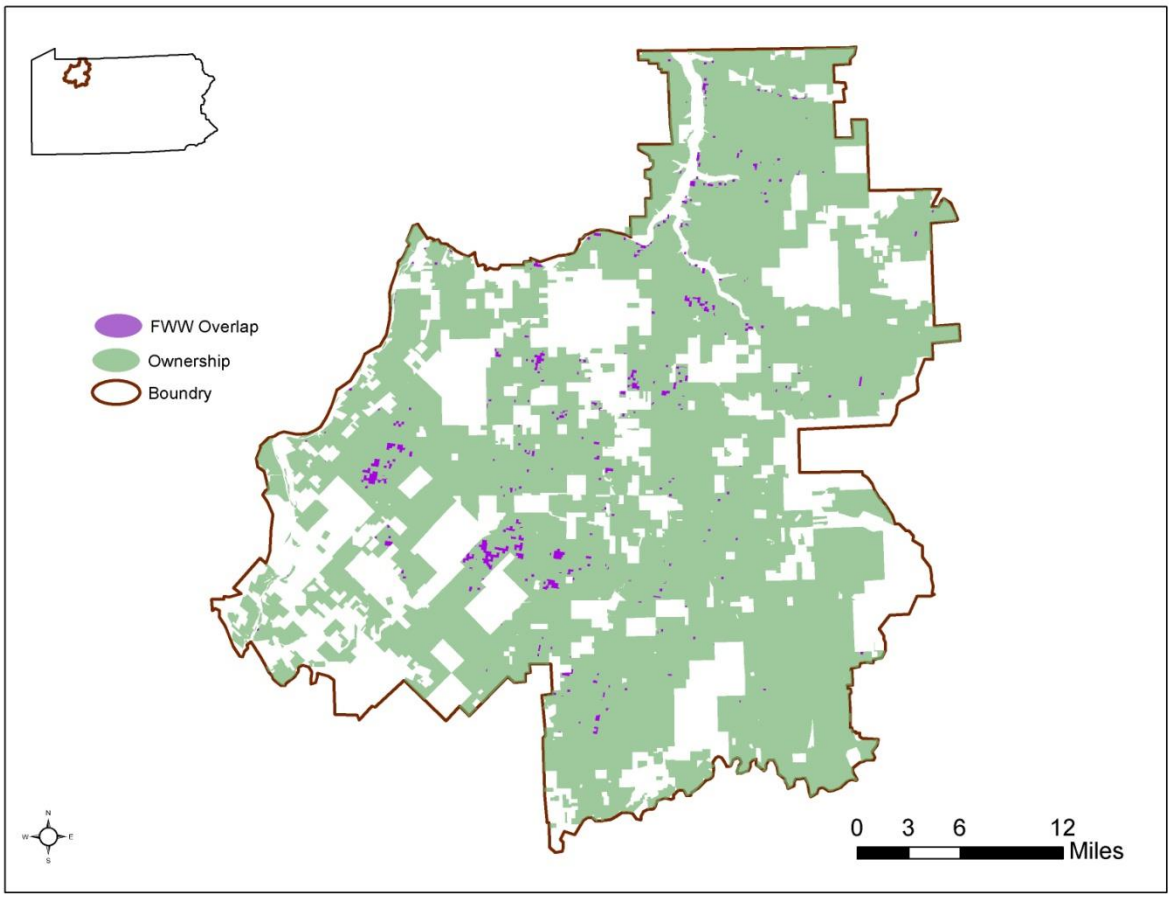

Figure 3. Forest disturbance on the Allegheny National Forest, Forest Disturbance Mapper, pixels with 2 years of disturbance based on assessment for September 29, 2011 and September 22, 2012 data.

presence of webworm nests), 2) determine the percentage of defoliation observed throughout the pixel (none, light (1-25 percent), moderate (26-50 percent), severe (>50 percent)), and 3) identify the species of trees being defoliated within the pixel. Field crews visited 33 of the 40 randomly selected pixels in 2011 and a total of 60 randomly selected pixels in 2012.

MODIS Accuracy assessment (Error matrix and Kappa Statistic)

We used a cross-tabulated error matrix (Johnson and Ross, 2008) containing rows, columns, and diagonals to calculate two statistics comparing the field data and MODIS-based data: overall MODIS data accuracy and MODIS data accuracy for each change category. We calculated the overall accuracy for the MODIS data by dividing the total number of correct classifications, obtained by summing the diagonal cell values in the error matrix, by the total number of field sites visited. We calculated the MODIS data accuracy for each change category by dividing the cell in the diagonal by its corresponding column total (Johnson and Ross, 2008). We used the Kappa statistic (Stokes et al., 2000) to assess the agreement between field observer data and MODIS NDVI data. The Kappa statistic is a measure of the agreement between two observations. It takes the form (Cohen, 1960):

$$k = \frac{Po - Pc}{1 - Pc}$$

where Po is the proportion of observed agreements and Pc is the proportion of agreements expected by chance (Sim and Wright, 2005). The kappa statistic is standardized to lie on a -1 to 1 scale, where 1 is perfect agreement and 0 is what would be expected by change, and negative values represent less than chance agreement. (Viera and Garrett, 2005). We also used the Jonckheere-Terpstra (JT) non-parametric test to compare between group (field observed defoliation level/MODIS NDVI percent change from baseline) and within group differences. For between-group comparisons, the null hypothesis that the distribution of observed defoliation does not differ with MODIS NDVI percent change was tested against the alterative that as MODIS NDVI percent change increases as the magnitude of observed defoliation increases.

Results

MODIS satellite data

MODIS satellite data collected from late September 2011 detected 9,991 acres of light change, 512 acres of moderate change, and 937 acres of severe change (figure 1). MODIS data collected for the same period in 2012 detected 14,942 of light change, 3,374 acres of moderate change and 2,256 acres of severe change (figure 2.) Overlaying the 2011 and 2012 MODIS NDVI data showed that 2, 920 acres had detectable change in both 2011 and 2012 (figure 3). The amount of detectable change increased from 11,440 acres in 2011 to 20,572 acres in 2012. The pattern of detectable change showed a trend from the northwestern side of the forest to the central and eastern side of the forest (figure 1 and 2).

Field crews detected fall webworm activity at 79 percent of the sites visited in 2011 and 78 percent of sites visited in 2012. The error matrices in tables 1 through 4 present data for assessing the agreement and disagreement between the MODIS-derived data and field survey data for 2011 and 2012. The shaded diagonal values show the agreement between the MODIS data and the field surveys; the other cells represent the disagreement (false negatives/false

positives) between the MODIS data and field surveys (Johnson and Ross, 2008). When comparing the MODIS data (detectable/ undetectable change) with the visual assessments of defoliation (defoliated/undefoliated), the overall accuracy was 42.4 percent for 2011 data and 20.3 percent for 2012 data (tables 1 and 2). The measure of agreement between field observed defoliation and detectable change measured by the kappa statistic was -0.1 (P = 0.67) for 2011 and 0.0 (P = 0.66) for 2012.

When comparing the MODIS NDVI percent change data (level of change) with the field observed defoliation level, the overall accuracy dropped to 30.3 percent for 2011 and 10.9 percent for 2012. The measure of agreement between field observed defoliation level and percent change measured by the kappa statistic was 0.1 (P = 0.28) for 2011 and 0.0 (P = 0.94) for 2012. The kappa statistic calculated for both the binary response (defoliated/undefoliated) and ordinal response (level of defoliation) for both years ranged from -0.1 to 0.1. Values in this range suggest no to very poor agreement between the field observations and MODIS NDVI satellite data (Monserud and Leemans, 1992). No significant differences, at the 5% level, was found for the ordering of the field observed defoliation level and the percent change MODIS NDVI data (Jonckheere-Terpstra Test Statistic = 218.5, P = 0.48) or in 2012 (Jonckheere-Terpstra Test Statistic = 815.0, P = 0.07). Suggesting that no significant relationship exists with increasing observed defoliation and increasing percent change detected by MODIS NDVI data.

Table 1. Cross-tabulated error matrix of Forest Health Technology Enterprise Team (FHTET) moderate resolution imaging spectroradiometer (MODIS) normalized difference vegetation index (NDVI) data (undetectable/detectable change) with ground survey defoliation data (undefoliated/defoliated) for fall webworm, September 29, 2011.

	FHTET MODIS data 2011			
Ground Survey	Undetectable change	Detectable change	Totals	Proportion (%)
Undefoliated	3	3	6	18.2
Defoliated	16	11	27	81.2
Totals	19	14	33	
Proportion (%)	57.6	42.4		
Overall accuracy (%)	42.2			
Kappa	-0.1			

Field crews noted that the majority of the trees experiencing defoliation were black cherry. Other species reported as being defoliated were ash, beech, and red maple. Overstory trees were the most defoliated with less defoliation occurring in the mid and understory trees. Fall webworm activity within the individual pixels was highly variable and “patchy” depending on the age and composition of the stand.

Table 2. Cross-tabulated error matrix of the Forest Health Technology Enterprise Team (FHTET) moderate resolution imaging spectroradiometer (MODIS) normalized difference vegetation index (NDVI) data (undetectable/detectable change) with ground survey defoliation data (undefoliated/defoliated) for fall webworm, September 22, 2012.

	FHTET MODIS data 2012			
Ground Survey	Undetectable change	Detectable change	Totals	Proportion (%)
Undefoliated	3	1	4	6.3
Defoliated	50	10	60	93.7
Totals	53	11	64	
Proportion (%)	82.8	17.2		
Overall accuracy (%)	20.3			
Kappa	0.0			

Table 3. Cross-tabulated error matrix of the Forest Health Technology Enterprise Team (FHTET) moderate resolution imaging spectroradiometer (MODIS) normalized difference vegetation index (NDVI) change data level with ground survey defoliation data level for fall webworm, September 29, 2011.

	FHTET MODIS data 2011					
Ground Survey	None	Light	Moderate	Severe	Totals	Proportion (%)
None	3	2	1		6	18.2
Light	8	3	1		12	36.4
Moderate	4	2	2		8	24.2
Severe	4		1	2	7	21.2
Totals	19	7	5	2	33	
Proportion (%)	57.6	21.2	15.2	6.1		
Overall accuracy (%)	30.3					
Kappa	0.1					

Discussion and Recommendations

Native insects such as the fall webworm occur throughout the region served by the Northeastern Area State and Private Forestry. The level of activity for these insects fluctuates based on several factors—the availability of host material, the condition of the stand, changes in environmental conditions, and populations of predators and parasites. The fall webworm is normally not considered a major forest pest for a few reasons. The defoliation occurs late in the growing season, the probability of outbreaks lasting longer than 1 to 2 years is low, and the number of native predators and parasites attacking this native pest is high. However, trees experiencing high defoliation will likely have reduced growth and some branch dieback.

Table 4. Cross-tabulated error matrix of the Forest Health Technology Enterprise Team (FHTET) moderate resolution imaging spectroradiometer (MODIS) normalized difference vegetation index (NDVI) change data level with ground survey defoliation data level for fall webworm, September 22, 2012.

	FHTET MODIS data 2012					
Ground survey	None	Light	Moderate	Severe	Totals	Proportion (%)
None	3			1	4	6.3
Light	18	1			19	29.7
Moderate	17		0	2	19	29.7
Severe	15	2	2	3	22	34.4
Totals	53	3	2	6	64	
Proportion (%)	82.8	4.7	3.1	9.4		
Overall accuracy (%)	10.9					
Kappa	0.0					

One of the purposes of this evaluation was to determine the current location and extent of fall webworm defoliation on the ANF. Historically, this would have been done by aerial surveys, which would have been used to detect and delineate outbreaks. Putting together an aerial survey over Federal land is a complex, costly, and risky endeavor. For this evaluation, we chose to use the available 240 by 240 m^2 MODIS NDVI data to determine the extent of the fall webworm outbreak across the ANF.

Although little agreement was found between the MODIS NDVI data and our field assessments of individual pixels the system did provide us with a relative rapid view of areas with change occurring. In discussions with both the FHTET and Eastern Forest Environmental Threat Assessment Center (EFETAC) work groups, areas of ~20 contiguous pixels (280 acres) were suggested as the basic unit of change that would require a follow-up field visit (William Hartlove, personal communication, April 4, 2012), not single pixels as was assessed in this project. An area of ~20 contiguous pixels roughly equals the ~300 acre average polygon size mapped during aerial survey flights in the Northeast (James Steinman, personal communication, May 31, 2012). It was also disclosed that because this is a 16 day composite product NDVI readings from individual pixels can occur at different times during this period or not at all. If no clear reading was collected due to clouds and other atmospheric issues the reading for that individual pixel may come from one or more previous cycles. This nuance of the data was one we were not aware at the beginning of the project and may have consequences for land managers trying to determine clear boundaries for areas with change. As with any new technology, it is critically important to evaluate the precision and accuracy of the data being produced. In this project we assessed the precision of two years of MODIS-derived datasets against field observed data. The MODIS datasets served their purpose by giving general "heads up" that something was occurring on the landscape, it also provide a general locations within the state/site to look, along

with a measure of the amount of change occurring within each area. This helped to define "hotspot" areas that had concentrations of pixels with detectable change, thus allowing a rapid assessment of the ANF and definition of areas where follow-up ground surveys could be conducted based on management and resource values in these general areas. It is hoped that as MODIS and other remote sensing data becomes more readily available and widely used, precision and accuracy assessments like this will become a standard practice that help better define the limitations and advantages of this technology.

Because fall webworm damage can be severe, keeping trees healthy is an important part of managing forest species. Maintaining proper stocking levels and reducing stand susceptibility by diversifying species composition can all be used to reduce the impact of insect and disease agents on ANF lands.

Because fall webworm is a native late season defoliator that appears to be moving across the forest control measures are not currently recommended in general forest areas of the Allegheny National Forest. We recommend that the Forest incorporate annual insect and disease monitoring into its management plans for high-value areas such as campground or parks and, if needed, apply both long- and short-term insect and disease treatment strategies to minimize impacts and meet resource objectives.

Acknowledgements
We are grateful to Andrea Hille and the staff of the Allegheny National Forest and to Vernon Thomas (FHTET), for providing the MODIS NVDI data for this project. Special thanks also go to John Stanovick (USDA, Forest Service, Northern Research Station) for statistical assistance and Ann Steketee (USDA, Forest Service, Office of Knowledge Management) for all the GIS and map work on this project.

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